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Self Pronation Assist below Elbow Prosthesis

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ABSTRACT

The Trans-radial amputation can significantly affect the level of autonomy and the capability of performing daily living, working and social activities. The current prosthetic solutions contribute to overcome the problem to a certain extent due to limitations of the upper limb prosthetic component availability. So, one common problem in trans-radial prosthesis is functional limitation of supination and pronation which results minimised ADL activities. As the pronation and supination movements is lost in ideal, short and very short level of trans-radial stump. Solutions to this formidable problem needs a provision of special design in the forearm to allow pronation in the terminal device whenever its required. Here in this study an innovative technique is introduced, which overcomes the above concerned issues i.e., current trans-radial prosthetic functional limitations, in terms of user's satisfaction and activities of daily living (ADL). The ultimate goal is to provide new design inputs in the upper extremity prosthetic field and, contemporary, increase user satisfaction rates and reduce device abandonment.

Keywords: Upper limb, Trans-radial amputation, Pronation, Wrist unit, ADL

INTRODUCTION

Major upper-extremity amputees account for only 8% of the 1.5 million individuals living with limb loss.[1] The human hand is a powerful tool for sensing and operating in the environment, as well as a very sophisticated means for physical and social interaction. It allows the human beings to accomplish sophisticated movements, from power to precision tasks, to the large number of Degrees of Freedom and the paramount role played by thumb opposition. Upper-extremity amputation is an accepted treatment option for acute trauma or sequelae of traumatic injuries, chronic infection, bone or soft tissue tumors, certain brachial plexus injuries, and complex regional pain syndrome. Regardless of the underlying diagnosis, emphasis is placed on definitively treating the underlying condition, achieving a stable, functional extremity, and minimizing painful sequelae. Patients and providers benefit from a multidisciplinary team consisting of experienced upper-extremity surgeons, skilled prosthetists and/or orthotists, physiatrists, pain management physicians, and therapists.[2]

Loss of upper extremity is directly proportional to the reduction of pronation

and supination motion of anatomical wrist joint. Pronation-supination is the motion of rotation of the forearm around its longitudinal axis. It is an important motion because it allows the hand to be oriented upwards supination and downwards pronation. This motion is added to those of the wrist flexion-extension, and radial and ulnar inclinations, and makes it a three-degrees-of freedom joint. With this possibility of orientation, the hand can take food from a table and carry it to the mouth-the vital function of feeding-and, thanks to pronation, it is possible to lean against an obstacle and overcome it. Supination is necessary to support heavy loads or pick up change at the supermarket. Supination is also indispensable to perform personal hygiene of the posterior perineum, a necessary condition for individual autonomy[3]

Upper limb prostheses can be classified into two main categories on the basis of their functioning: passive prostheses (which in turn are divided into cosmetic and functional) and active prostheses (which include body-powered and externally powered). Cosmetic prostheses mainly aim at the aesthetic substitution of the missing body part, while functional prostheses have the purpose of facilitating very specific activities, such as those related to work or sport.[4]

One of the main limitations of current upper extremity prosthetic devices is represented by the lack of pronation and supination and reliable function of terminal device. Finally, the necessity of an extensive training required to properly manage the artificial hand & movement limitations make the prosthetic hands still far from fully addressing the users' needs.

Therefore, we have designed this pronation assist below elbow prosthesis on the analysis of user needs; the ultimate goal is to provide pronation of the terminal device so that prostheses should have to increase user acceptability.

MATERIALS AND METHOD

SUBJECTS

The patient was a 32-years-old who went through trans-radial amputation due to RTA. He reported at AIIPMR OPD for prosthetic management. He was referred to the Department of Orthotics and Prosthetics in the All-India Institute of Physical Medicine and Rehabilitation (AIIPMR), for the provision of a suitable prosthetic management. The patient gave a written informed consent to participate in the study, and appropriate approval was also obtained from the Institutional Ethical committee. A detailed assessment was performed with demographic data, medical history, radiographic image, and functional outcome.

OBJECTIVE

The study was aimed to design a cost-effective & functional prosthesis for trans-radial amputee to provide necessary movements around the wrist and to restore the required specific activities with ease and comfort.

DESIGN CONCEPT

The designed functional prosthesis utilized some existing components for upper extremity prosthesis. Those are Robin aids soft mechanical hand (voluntary opening), Quick change wrist unit, Forearm piece, Socket, Triple control cable system and figure 8 harness system.

The ingenious forearm rotational unit is a metallic design which comprises of outer ring, inner ring (rotational) and connecting rod. Connecting rod and the two stoppers placed on the outer ring. The distal end of the socket is attached to these components.

Outer Ring:

The fixed outer ring has two stoppers placed on it. Inner ring is moving in rotational motion because of the 2 stoppers placed on the outer ring. 45 degree of rotation is allowed in inner ring due to the position of stoppers. The position of

stopper is side sensitive. In the current design, placement of stopper is for right-hand terminal device.

Inner Ring:

The resting position of the terminal device is mid prone. With the help of control cable system inner ring moves to one end of the stoper causing pronation of forearm piece. Connected forearm piece and the terminal device also moves along with the inner ring. At the end of full pronation, the terminal device gets locked. With the help of control cable, the lock releases.

A rubber band in the rotational device elongates with pronation which stores potential energy. The stored energy helps the terminal device to return to its original position. Along with the inner ring the forearm and the terminal device is also back to the first position.

Connecting Rod:

Connecting rod is the interlink between the forearm rotational unit and the socket. It helps to transfer the forces from the socket to the forearm rotational unit. This is an aluminium rod having threads in the proximal part which gets fixed in the threads of the wrist stud. The wrist stud is attached to the distal end of the socket.

(Fig-1)

(Fig-2)

Figure – 1: Shows the position of the inner ring component which moves from one end of the stopper to another end.
Figure – 2: Shows the connecting rod attached from socket to the forearm rotational unit.

Forearm piece and Socket

Commonly, in below elbow prosthesis, socket and the forearm piece are inseparable and laminated as a single piece. Contrast to that in this design, the forearm piece and socket are laminated separately and not fixed with each other. One end of the connecting rod is attached to distal end of the socket and is connected to forearm rotational unit at the other end. Also, the separate forearm piece is attached to the rings of the rotational unit by means of screws and nuts. The arrangement of the forearm part of the prosthesis is such that, the rotational unit is present inside the forearm piece and the socket and forearm piece are aligned in one straight line/plane. In order to avoid contact between the connecting rod and the stump, build ups to be made at the end of the socket with MCR rubber.

Control Cable System

The prosthesis employs three cables for the operation of the prosthesis. A cable is attached to a screw attached to the forearm rotation unit anteriorly. The screw which joins the forearm rotational unit to forearm piece. Proximally the cable is attached to a base plate retainer antero-distal part of the socket and runs upwards to anterior part of Y strap. Another cable passes parallel to the rotational cable and runs through a base plate retainer and a locking mechanism at the antero-medial aspect of the socket. The third cable to operate the terminal device is same as the existing functional prosthesis. Rotation of the terminal device is operated by shoulder abduction and elbow extension.

(Fig-3)
Figure – 3: Pronation assist below-elbow prosthesis

RESULTS & DISCUSSION

This forearm rotational unit was designed, developed and applied on a trans-radial amputee and found to be effective. The rotational unit was easy to operate and comfortable. It achieved the goal i.e.; the subject could perform the daily living activities with ease and comfort.

Study suggests that to perform most of the ADL activities 53degree of forearm rotation is required.[6] Based on such studies the rotational unit is designed such that it provides 45-degree pronation of forearm piece and terminal device. So, this prosthesis helps to carry out daily living activities required in pronation without using the contralateral limb and without prepositioning the terminal device. It makes the patient independent as he can self-pronate his terminal device and needs not to preposition it by the sound limb. So, the contralateral limb or the sound limb is free to work for other activities.

Limitation:

Along with all the advantages, this device has also one drawback i.e., cosmetically less appealing and bulky.

CONCLUSION

This pronation assist below-elbow prosthesis can be an effective treatment option in trans-radial amputation. Because of low cost, light weight and flexibility with all below elbow level of amputations, and specially it allows the pronation movements. Due to low cost, it will be mainly preferred by lower economic group patients in developing countries.

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